PERSPECTIVE

Fate of the Estuary

Luna Leopold,
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The restoration, and thus the fate of this unique geographic feature, the Estuary, is influenced by, and ultimately dependent on, three things: science, the application of knowledge derived from science, and the operating administrative-political forces.

If there is validity to this simplified characterization of a complex subject, then it follows that we should pay attention to these principal forces, and not be satisfied with lengthy discussions of peripheral matters that are of small importance to the larger picture.

The kinds of questions that will no doubt arise include the following: Where in the watershed are the principal sources of sediment and contaminants and what processes provide them? What is the effect of tidal marshes on the sediment budget and on the tidal prism of the whole Bay? How do marshes act as filters of sediment and contaminants, and what is the relation of plant architecture in the marsh to the filtering effect?

Exploring such questions will take time and effort and all proposed shortcuts must be viewed with skepticism.

"The best science and its most useful application may be negated by failure of the administrative-political establishment to draw some limits on the exposure of the ecosystem to the overpowering destructive pressure....of our national pursuit of unlimited growth."

To make the best use of science, it would be well to develop a carefully chosen list of the major scientific questions that stand unanswered. These might be divided into different magnitudes of scale such as regional problems, subregional problems and local ones.

In what direction will the scientific capability be deployed? It might be argued that more is known about the Bay itself than about the relation of the Bay to its watersheds. We can expect an increasing pressure to develop new knowledge about watershed functions, but it must be realized that the watersheds involve more diverse problems and different circumstances than occur in the Bay's waters and on its shores. This complexity poses a conundrum in that the administrative-political arms want answers that come quickly and with assurance. These expectations are antithetical to the operation of good science which is usually time-consuming and provides a tentative and far from assured answer. Most will require field observations and cannot be solved even with the most sophisticated computer models.

With regard to the application of science, we now have an organized and practical program of monitoring trace elements in bay waters. However, we are far from sure how to use this information to influence the production of, or ameliorate the effects of, undesirable trace elements.

The U.S. Geological Survey has made great contributions to knowledge of the Bay in their studies of circulation of bay waters, of primary production, of benthic cores, to name just a few subjects.

On wetlands that border the Bay, we have just completed a study of the goals indicating what habitats in what quantities seem desirable for the health and welfare of the ecosystem. This is a real accomplishment in the application of scientific knowledge to practical problems. This project has involved hundreds of experienced people all volunteering their help. The next step, monitoring change and hopefully progress, is still ahead.

Another valuable application of science to practical problems is the development of the S.F. Estuary Institute's EcoAtlas. It shows in amazing detail on maps the ecotypes in the Bay region as of 1800 AD and again in the present year. Knowledge of original conditions is essential for estimating the possible endpoints of restoration attempts.

These examples of application of scientific knowledge remind us that science gives us results that are often hesitant, partial and sometimes useless. But these qualifications of the expectations of science should not be considered too discouraging, in view of the administrative-political milieu in which bay restoration exists. There is a large variety of federal, state, and private organizations, each having particular interests and backing, as well as dedicated public groups devoted to preserving and improving the Bay. All are under the crushing force emanating from the national pursuit of unlimited growth.

This relentless striving for expansion applies increasing stress to all natural systems and is felt in the Estuary in a multitude of ways. The best science and its most useful application may be negated by failure of the administrative-political establishment to draw some limits on the exposure of the ecosystem to overpowering destructive pressure. Mitigation of destructive action, even when successful, is ultimately an admission of defeat.

We must persuade the American public that it is in their interest to slow, if not stem, the forces that tend to destroy our ecological base. It is my opinion that science, and the application of science, will not accomplish the aims that will be elucidated in the present conference. Rather we must give highest priority to altering those administrative-political forces that contribute to degradation of the Estuary (Leopold, SOE, 1999).

MEASURING AND MODELING TOOLS

NUMERICAL MODELS: IMPLICATIONS FOR RESTORATION

Stephen Monismith, Stanford University

Numerical models are a major tool for assessing the environmental impacts of engineering works in the Bay-Delta system,and for trying to predict what changes in circulation might accompany physical changes in the Estuary due to restoration or re-plumbing projects.

Several types of model are currently being used for this purpose, each suited to addressing different classes of questions and each with significant limitations:

- Statistical models like the "G" model or Flow-Salinity relations are best suited to address changes in salinity due to changes in bulk parameters like reservoir releases or Delta pumping. They cannot be used to say anything about transport of organisms or biogeochemistry of the system.
- Properly calibrated one-dimensional channel network models like DSM2 can represent effects on salinity and on organism transport of some forms of system modification, most notably the operations of in-channel gates, or the addition of narrow channels to the existing plumbing. However, they cannot predict the behavior of large open areas such as might be created by breaching levees.
- Two and three dimensional circulation models build in more physics and thus have greater predictive capabilities. Because they make few assumptions, state-of-the-art three dimensional models can be used to predict the effects of a wide variety of engineering actions on circulation patterns and transport rates. However, these models require accurate bathymetry and run slowly on currently available platforms. They also work best when high quality data are available for their calibration and validation.

Unlike physical models of the Bay, numerical circulation models can be used in conjunction with models of phytoplankton growth,nutrient dynamics, or even with models of the behavior of individual organisms like zooplankton or bivalve larvae, to make inferences about how changes in the physical system might affect ecosystem processes in the Bay.

In terms of long-term utility, it may be time to develop a three dimensional circulation model, named (as a strawman) "Bay Model 2000," covering all of the Bay Delta system as well as the adjoining coastal ocean. This model could be viewed as a 21st century replacement for the physical Bay model in Sausalito. It would take advantage of modern parallel computational technology to operate at a useful speed, i.e.,much faster than real time. In practical terms this means that it would likely be a numerical model written to run efficiently on a large (and fast) network of desktop computers. Like models used to do weather prediction,it would maintain accuracy by assimilating in real time the many available data streams such as those coming from sensors located throughout the system and operated by the Department of Water Resources, the U.S. Bureau of Reclamation and the National Oceanic and Atmospheric Administration. Finally, unlike the existing physical model,this computational Bay model could be used (for example) to drive models of phytoplankton dynamics that would be used to assess the risk of harmful algal blooms arising as a consequence of the creation of new shallow water areas in the Delta.

There is the question of how numerical models might be used to assess the impacts of restoration of the Bay-Delta system. It is possible to assess, with reasonable confidence, salinity effects of policies and facilities, as well as changes in entrainment of passive particles into the pumps. It may be possible to generate "ballpark" estimates of changes in primary production,as well as changes in rates of sediment deposition,erosion and transport. Understanding of both these important basic ecosystem processes is limited, however, and both are currently the subject of CALFED-sponsored research by the U.S. Geological Survey. Thus, in reality the jury must be considered out on our ability to model them. Lastly, essentially nothing is known about exchanges between the Bay and the ocean, and how ocean conditions might affect populations of organisms that live in both for parts of their life cycles, and little is understood about how primary production is linked to higher trophic levels. For example, even the large perturbation to the system that one might infer the Asian clam, *Potamocorbula amurensis*, has wrought is the subject of much ongoing debate, and shows how far we are from being able to understand how changes to the overall system might ultimately play out (Monismith, SOE, 1999).

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NEW SCIENCE

Floodplain Modeling

A preliminary model combining hydrology and population dynamics suggests that flooding can significantly impact splittail viability in the Delta. It is now recognized that floodplain processes should be restored to rehabilitate the Bay Delta ecosystem including native fish inhabitants (CalFed ERPP Vol. I, 1999). There is still debate, however, over the quantity and location of habitat to be restored. Models are useful tools for establishing objectives, selecting among alternatives, determining appropriate indicators and associated "performance metrics" and interpreting monitoring information to assess progress.

Researchers developed a floodplain modeling tool to investigate possible effects of floodplain habitat restoration in the Sacramento delta ecosystem. Conceptual and mathematical models were created to illustrate a method that is both scientifically rigorous and relevant. The modeling approach combines a hydrologic model with population modeling techniques to investigate the possible effects of expanding the area of flooding and timing of inundation on splittail population viability in the Yolo Bypass. Splittail live for 5 - 7 years, spawn on flooded vegetation and are highly fecund, which is believed to allow the population to rebound during wet years when the bypasses are flooded (Caywood 1974, Meng and Moyle 1995). The preliminary model suggests that changes in egg mortality (affected by floodplain inundation) can significantly impact recruitment rates and overall population viability.

Formulation of a useful model for investigating possible population responses to various management scenarios requires a description of the dominant sources of variability at various stages of the splittail life cycle. This modeling project, which is still in its infancy, has largely demonstrated the utility of such an approach and pointed to the importance of acquiring data on splittail-habitat relationships (Pawley, SOE Poster, 1999).

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PROJECT IN ACTION

Modeling Salinity Impacts of Suisun Levee Breaches

Modeling research examining the assumption that 1998 breaches in Suisun Marsh levees would lead to higher Bay and Delta salinity suggests that the actual response is more complex. In February 1998, the tidal prism of Suisun Bay was expanded by 40% when spring tides, low pressure, storm winds and El Niño ocean conditions combined to breach or overtop levees in more than 60 locations in Suisun Marsh. To evaluate the potential impacts of not repairing the levees, researchers from the Department of Water Resources conducted a hydrodynamics and salinity modeling analysis — simulating historical hydrology, facilities configurations, and water project operations between October 1991 and September 1994. This approach provides enough time for the salinity response to propagate through the system and affords the opportunity to examine impacts for three dry years and one wet year.

Researchers also examined the sensitivity of salinity mixing to breach size, location and extent of inundated area. Two breach configurations were simulated: first, the February 1998 flood as eleven breaches of 100-feet-wide by 10 feet below MLLW (mean low lower water); and second, as expanded breaches comprising 10-40% of the exterior levee perimeter. Two additional four year simulations explored a hypothetical levee failure on the San Joaquin River side of Sherman Island.

Findings suggest that the salinity response of this type of event depends on the complex balance between friction, bathymetry, tidal prism, and tidal range/tidal excursion. General observations are: 1) salinity is increased in western Suisun Bay but reduced in the north and south Delta. The magnitude of the change, and the location of the cross-over between salinity increase and reduction, is a function of the configuration and location of the levee breaches; 2) the tidal range is reduced up to one half foot along the axis of the Estuary and the average water level is reduced in the Delta (see chart); 3) over half the inundated area volume is exchanged through the levee breach at each tide. CALFED responded to this research by setting up a Suisun Marsh levee investigation team to determine costs and benefits of including these levees in their overall levee rehabilitation program, and to identify beneficial linkages with CALFED's other programs. Subsequent focused modeling analysis by the team suggests that carefully designed restoration and levee breach projects in the marsh could provide opportunities for win-win ecosystem and water quality improvements (Enright et al, SOE Poster, 1999).

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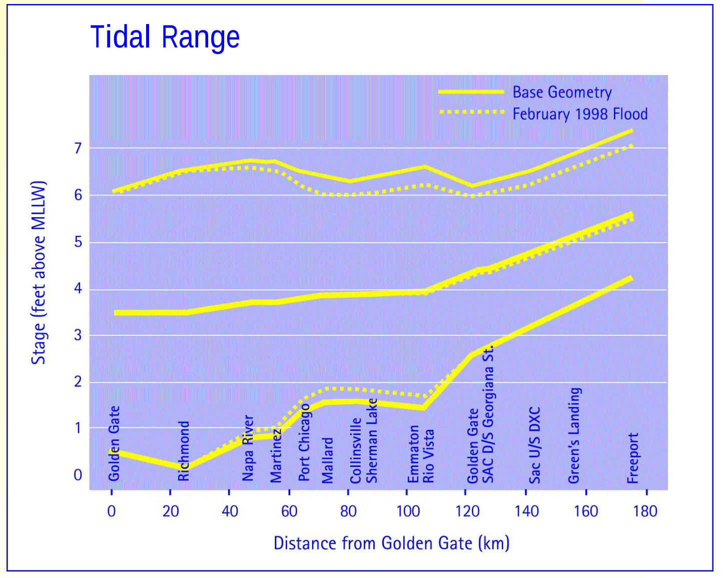

28-day average tidal range between Golden Gate and Sacramento via Sacramento River.

CHOOSING THE BEST MAP
AVAILABILITY, ACCURACY AND ACCOUNTABILITY

Zoltan Der et al, San Francisco Estuary Institute

The use of computerized Geographic Information Systems (GIS) is rapidly increasing among government agencies and environmental interest groups as they work to document, protect and restore the landscapes and resources of the Bay Area.GIS — maps produced from layers of digitally based geographic information — is evolving from "maps of maps" to Internet search engines that provide access to spatial data and their sources through interactive maps on-line.

But the increased use and improvements in GIS do not necessarily mean that maps have gotten better. In many cases, GIS seems to conceal the errors of existing maps, or it creates new maps with their own errors. Many maps that exist as part of GIS are not available to people who do not have the same GIS. Digital maps can also imply an undue amount of map certainty or accuracy. For example, the zoom feature of a GIS or any other software for viewing digital maps can make possible a closer examination of boundaries and detail than is supported by the original maps or their sources of information. Overlays of maps in a GIS can suggest more or less spatial correspondence between features than really exists. And there are choices in digital maps for many places. All of this raises some practical questions:which map is best, how are the choices compared, and how should the errors of a digital map be displayed?

The San Francisco Estuary Institute was asked by the Marin County Community Development Agency to help address these questions with regard to existing maps of the historical uplands margin of the San Francisco Estuary in Marin County. The Agency intends to use a map of this boundary for long-range land use planning. The Institute and the Agency worked with partners in and out of government to identify four maps to be compared. All of these maps were being used in one form or another by agencies, consultants and the concerned public. At issue was the fact that each map showed a different boundary, and that the Agency lacked sufficient rationale to choose between the maps.

On behalf of the Agency, the Institute developed a detailed understanding of the original purposes and methods of production and reproduction of the various maps, based upon their written documentation and interviews with their authors. The Institute then made a detailed study of all possible spatial errors for each map. A flow chart was constructed to show how errors might inter-relate, and the total spatial error for each map was quantified. Finally a composite map was made showing the comparable boundary lines, in the context of their probable errors. The Institute deferred to the Agency for any decisions about the relative values of the maps.

The study provided the following conclusions and recommendations. Firstly, no map is useful unless it is readily available. All the maps have met their original,intended purposes. Cartographic errors that result from misinterpretations of the landscape, either in the field or the office, tend to be much greater than errors incurred during map production or reproduction. The needed accuracy of a map depends on its intended use;a general land use plan may not require the most accurate map. Accountability may be more important than accuracy, especially when choosing among maps that are equally inaccurate, in the context of their intended use. And finally, line thickness or buffers should be used in a GIS to display the expected error of important boundaries (Der et al,SOE Poster, 1999).

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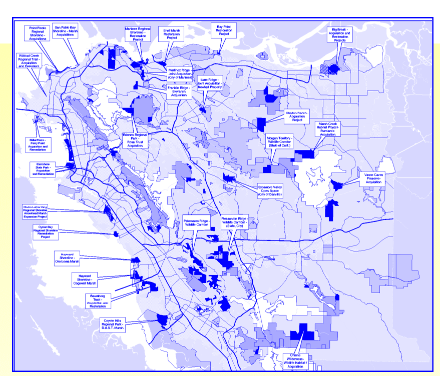
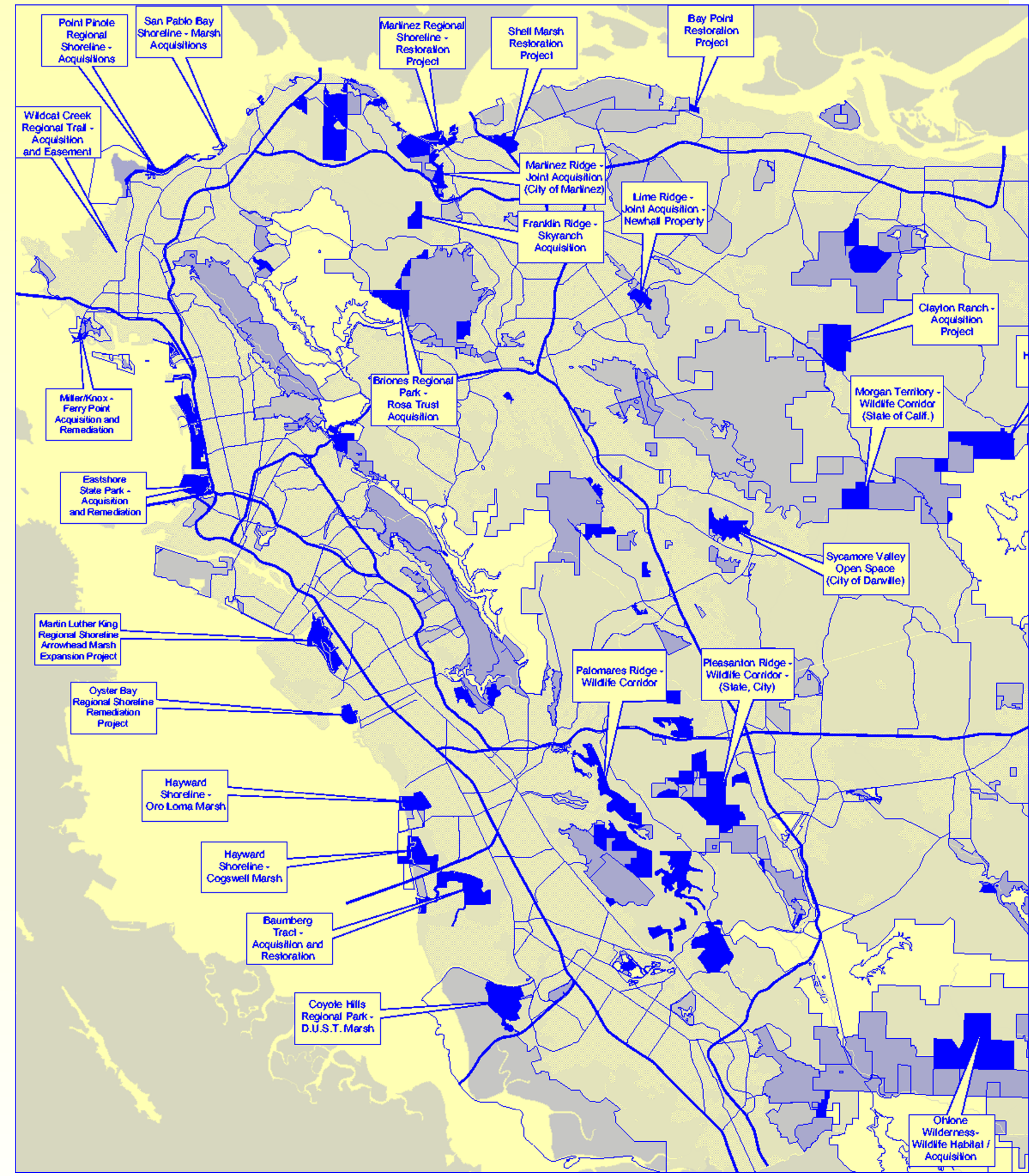
PROJECT IN ACTION
Acquisition, Enhancement and Restoration Projects in East Bay Parks

The GIS map opposite highlights some of the East Bay Regional Park District's parks, open space and trail facilities in Alameda and Contra Costa Counties, and shows lands the District is helping to enhance or preserve through environmental partnerships. The District currently operates 55 parks and open space areas, manages more than 91,000 acres of land, and is leading or participating in more than 15 enhancement and restoration projects along the San Francisco Bay shoreline. A large percentage of these projects have focused on restoration and management of tidal marshlands and other aquatic habitats to benefit such species as the salt marsh harvest mouse, Delta smelt, California clapper rail, least tern and soft bird's beak. Other shoreline projects focus on the restoration of coastal prairie, riparian areas and seasonal wetland habitats to benefit other species, including Santa Cruz tarplant, snowy plover and burrowing owl. The district is also making a substantial commitment of resources to manage and protect these restored habitats from a variety of natural and human-related threats, including control of introduced predators and non-native vegetation (eastern cordgrass and artichoke thistle, for example), and the remediation of soil and groundwater contaminants (Olson, SOE Poster, 1999).



PROJECT IN ACTION
East Bay Parks continued



PERFORMANCE CRITERIA

FOR IMPLEMENTING A NO NET LOSS OF WETLANDS POLICY

Andree Breaux et al,
S.F. Bay Regional Water Quality Control Board

In California, the state regulates all discharges to its waters and wetlands under the Porter Cologne Act, and the California Wetlands Conservation Policy requires that there be no net loss of wetland acres or values. At the federal level, wetland policy in the United States is also guided by the goal of no net loss of wetland habitat, and is enforced primarily through the permitting requirements instituted under the Clean Water Act. Under these regulations, a permit applicant is required to provide compensatory mitigation when wetland loss cannot be avoided or minimized. Such projects generally take the form either of the restoration of previous wetland sites or of the creation of artificial wetlands on upland sites. The progress of wetland development is usually measured by performance criteria which are standards set on a project-by-project basis to assess functional changes or ecosystem development in compensatory wetland mitigation projects. Determining the success of these projects can sometimes be difficult since wetlands develop like gardens, with some elements planned but others not. So, while we are ensuring that there is no net loss of acreage, it is difficult to ensure no net loss of functions. This research reviewed some of the typical performance criteria used to track ecosystem changes in wetland compensatory mitigation projects proposed or permitted between 1988 and 1995 in the San Francisco Bay region.

The three tables shown on these pages (pp. 67-69) summarize research findings. Between 1988-1995, as a result of 116 compensatory mitigation projects in the Bay region, 548 acres of wetlands were lost and 619 gained (plus 653 in indirect gains). Among the projects, over 50 different parameters were measured to assess wetland development and function, and project "success." The most measured feature of compensatory mitigation sites was vegetation, with hydrology a distant second. Wildlife was measured but usually only as a qualitative assessment of "evidence of use." Target wildlife frequently consisted of endangered or threatened species. The least cited criteria were water quality, soils and invertebrates.

The following organizes the results by the most-cited performance criteria within each of the three predominant wetland project types.

Riparian (36 of 116 projects)

- The target vegetation for such projects consisted predominantly of tree species, such as the coast live oak (*Quercus agrifolia*), California buckeye (*Aesculus californica*), red willow (*Salix laevigata*), valley oak (*Quercus lobata*), sycamore (Plantus racemosa), white alder (*Alnus rhombifolia*), cottonwood (*Populus fremontii*), and coffeeberry (*Rhamus californica*).
- Percent cover was cited as a performance criteria in 26 of the riparian projects.
- Percent survival was listed as a performance standard in 22 of these projects. Within these 22,9 set a goal of 75% survival after 5 years; 4 set a goal of 80%; and 2 set a goal of 90%. The remaining 7 projects using percent survival as a criterion had a variety of targets, such as a comparison of the planted site to a reference site after 10 years; a 50% survival of planted vegetation after 3 years; and 75% after 2 years.

Perennial Tidal (27 of 116 projects)

Perennial tidal systems include all tidal or estuarine wetland projects that target saline, brackish, or more rarely, freshwater vegetation systems, and which are influenced by the tides.

- The target vegetation of this type of wetland included predominantly salt marsh vegetation, since most of the wetland sites were saline or brackish.
- Twelve of the reports used percent cover as a criteria, with figures set between 70% and 90% after five or six years.
- Six reported no performance criteria at all.

Perennial Non-Tidal (3 of 116 projects)

Perennial non-tidal includes freshwater systems. This category is noticeably small because most of what is generally classified as freshwater emergent has been placed under freshwater seasonal.

- Perennial non-tidal fresh systems generally target *Carex sp., Scirpus sp., Juncus sp.*, and often are designed to include trees.
- Two of the three cited 75% cover in five years.
- The third cited 75% survival after five years.

Seasonal Wetlands (33 of 116 projects)

Seasonal wetlands are defined as wetlands that have seasonally saturated soils or are periodically flooded. They include all ranges of salinity, and they embrace both diked and non-diked areas.

- While vegetation was the single most-cited criteria in the other categories of wetlands, hydrology was the most cited criteria for this category. Criteria were diverse: One project stated a requirement for ponding through May, but set no quantitative objectives; others required documentation of the saturation and ponding at several predetermined points at the beginning and end of the autumn rains; one project set a performance criterion as soil saturation (within the root zone) for at least 30 days of the growing season in at least three of five monitoring years; another project set two hydrology targets — one for a channel system with the seasonal wetland requiring inundation of 21 consecutive days (8% of the growing season), and the second for a seasonal pond area requiring inundation of at least 13 consecutive days (5% of the growing season).
- Percent cover was also used often in seasonal wetlands. For those that did not set cover as a comparison to reference sites, the range was between 70% and 90%, with most projects fixing on 75% or 80%.
- Five of the 33 projects contained no information on performance criteria.

In conclusion, the selection of adequate performance criteria is crucial if wetland regulators are to

WETLAND ACRES LOST AND GAINED

In the 116 Bay Area Projects Examined For 1988-1995

Wetland Losses:	548 acres
Direct Wetland Gains:	364 acres created
	118 acres restored
	137 aces of upland buffers planted
Total Direct Gains:	619 acres
Indirect Wetland Gains:	599 acres enhanced
Preserved Wetlands:	28 acres preserved
Miscellaneous Gains:	26 acres
Total Indirect Gains:	653 acres

PROJECT IN ACTION

Adaptive Management on San Diego Bay

At San Diego Bay's Sweetwater Marsh National Wildlife Refuge, the inclusion of a strong research component in a mitigation program made it possible to document outcomes of habitat creation efforts and to explain many of the causes. As in San Francisco Bay, the coastal wetlands of San Diego Bay support multiple endangered species, three of which were jeopardized by new construction projects (a highway and flood control channel). Because endangered species were involved, damages to habitat had to be mitigated, and strict compliance criteria had to be met.

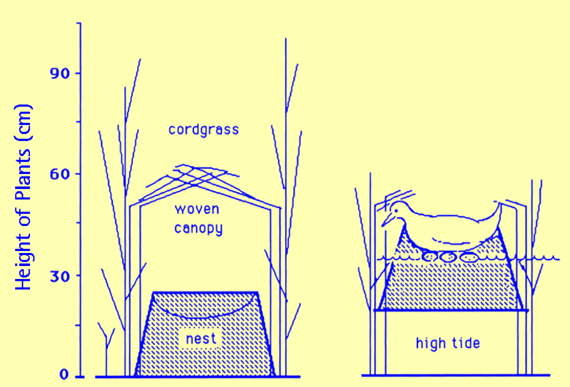
Studies of habitat created for the three species began five years after the first mitigation site was excavated in 1984. Research included the development of assessment tools to determine compliance with mitigation requirements and sustainability; remote sensing to quantify the area of different habitats; spatial monitoring of endangered plant populations using global positioning and GIS; and experiments to test alternative soil amendments.

The assessment program documented compliance for two species (California least tern and salt marsh birds beak —a plant) but not for the third (light-footed clapper rail). For the tern, the mitigation requirement was to construct channels that would support the tern's favorite food (fish). Researchers compared fish samples in the new channels with those in natural channels and found that compliance was achieved in year three.

For the bird's beak, mitigation required re-establishment of a previously extirpated population. Seeds were sown for three years and the resulting population complied with standards in 1995. But the population shrank in 1996, a drought year. Follow-up research suggested that more attention be paid to factors limiting seed production (such as nitrogen and pollinators) and to control of exotic annual grasses. Bird's beak is a hemiparasitic plant that taps into a host plant for water and nutrients, but the exotic hosts are annual (unlike the perennial natives) and they die before the birds beak achieves maturity.

For the light-footed clapper rail, mitigation required three things: crabs for food, a high-tide refuge, and nesting habitat. Researchers found that habitat had serious short-comings, namely coarse soil, low nutrient supplies, short vegetation, scale insect outbreaks, and inadequate nesting habitat for rails. Rails never nested in the marshes designed for their use. The main problem turned out to be that the cordgrass was too short to be woven into a protective nest canopy (see diagram).

Clapper Rail Nesting Needs



Further assessment suggested that the substrate was too sandy to supply enough nitrogen for the plants to grow tall, and that the plants were too short to support ladybird beetle predators of the scale insect that was damaging the cordgrass. A ten-year data set predicted that soil development would take at least 40 years to match conditions at the nearby reference site. Because the height of the cordgrass was actually declining, it was unlikely that cordgrass would ever reach height standards.

Collegial interactions among all the members of the adaptive management team (the mitigators, regulators and scientists) and trust in the scientific findings were instrumental in gaining concurrence that the mitigation project met criteria for two of the endangered species but not the third. The team agreed that an alternative penalty should be set for damages to the light-footed clapper rail.

Experience at San Diego Bay has broad application. The work pinpoints five ecosystem components that should not be ignored in restoration: anthropod predators, plant canopy structure, soil structure, soil nutrients, and site landscape interactions (Zedler, SOE, 1999).

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PARAMETERS MEASURED

In 116 Bay Area Compensatory Mitigation Projects 1988-1995

	Total Number of Projects	% of Projects Measuring Parameter
VEGETATION		
Percent Cover	84	72%
Percent Survival	59	51%
Species Diversity/Richness	41	35%
Vigor	32	28%
Species Dominance	31	27%
Height	30	26%
Natural Regeneration/Recruitment	6	5%
Basal Area	5	4%
Productivity	5	4%
Canopy Stratification	4	3%
Root Development	4	3%
Density	3	2%
HYDROLOGY		
Surface Water Levels	26	22%
Channel Geometry and Stability	23	20%
Depth and Duration of Ponding	22	19%
Inundation	18	15%
Sedimentation Rates	16	14%
Tidal Monitoring	13	11%
Salinity as Conservative Tracer	9	8%
Groundwater	8	7%
Elevation	7	6%
Velocity/Flow Rates	6	5%
Pore Water	5	4%
Soil Saturation	3	3%
WATER QUALITY		
Temperature	8	7%
Conductivity	5	4%
Dissolved Oxygen	5	4%
pH	4	3%
Turbidity	2	2%
Nitrogen	2	2%
Phosphorus	2	2%
Coliforms	2	2%
Biological Oxygen Demand	2	2%
Heavy Metals	2	2%
Organics	2	2%
Chlorophyll a	1	0.1%
Ammonia	1	0.1%
Total Organic Carbon	1	0.1%
Total Suspended Sediment	1	0.1%
Sulfide	0	0%
Pesticides	0	0%

	Total Number of Projects	% of Projects Measuring Parameter
SOILS		
Grain size	4	3%
Nutrients	2	2%
pH	2	2%
Salinity	2	2%
Soil colors related to saturation/oxidized root channels	2	2%
Texture	1	0.1%
Porosity	1	0.1%
Moisture	1	0.1%
Conductivity	1	0.1%
INVERTEBRATES		
Benthic Organisms	4	3%
Algae	2	2%
Phytoplankton	1	0.1%
WILDLIFE		
Evidence of Use	44	38%
Target Habitat	14	12%
Population County	14	12%
Diversity/Richness	12	10%
Egg Count	2	2%
Behavior	1	0.1%

be required to assess overall wetland losses and gains, as well as the success of individual compensatory wetland mitigation projects. What is adequate will depend in part on site specific features, but should also follow some general framework for what is measured, and how and when.

This research begins the process of standardization by simply finding out what has been measured as performance criteria in compensatory wetland mitigation projects between 1988 and 1995. For tidal wetlands the results conform to the literature indicating that percent cover is the most frequently used parameter to determine project success or failure. In general,75% cover appears to be the conventional and adequate measure of success for tidal wetlands. In regard to riparian wetlands, the use of vegetation as a criteria requires further agreement as to whether percent cover or percent survival is the best criteria to use. For seasonal wetlands, the determination still remains as to what the length of the growing season should be and how long ponding should continue to accommodate biological species.

Future functional assessments should include detailed baseline studies at both the compensatory wetland mitigation sites and the potential development sites to determine where and how potential functional losses could occur. Monitoring requirements should be based on the size of the compensatory wetland mitigation project, with larger sites requiring more detailed assessments for a longer period to minimize wetland functional losses (Breaux et al,SOE Poster, 1999)

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TYPICAL WETLAND BENEFICIAL USES OR FUNCTIONS

- Groundwater Discharge
- Warm Freshwater Habitat
- Groundwater Recharge
- Estuarine Habitat
- Baseflow Augmentation
- Freshwater Replenishment
- Flood Storage Desynchronization
- Marine Habitat
- Nutrient Processing
- Fish Migration Habitat
- Sediment/Toxics Retention
- Fish Spawning Habitat
- Education/Research
- Wildlife Habitat
- Uniqueness/Heritage
- Preservation of Rare, Endangered Species Habitat
- Economics
- Navigation
- Ocean-commercial and Sport Fishing
- Aesthetics
- Areas of Biological Significance
- Shellfish Harvesting
- Plant Communities
- Agricultural Supply
- Cold Freshwater Habitat
- Industrial Service Supply
- Contact Recreation
- Non-contact Recreation

NEW SCIENCE

Monitoring Dredging Effects on Eelgrass

A new approach for monitoring the effects of dredging events on eelgrass beds — monitoring required by local agencies — was used in the Richmond Harbor Navigation Improvements Project in San Francisco Bay, California. The approach was based on the relationship between light availability, as indicated by photosynthetically active radiation (PAR), and the estimated hours of irradiance-saturated photosynthesis (Hsat) required to maintain whole plant carbon balance and growth. Daily average Hsat values were calculated from PAR measurements and compared to threshold Hsat values required for maintaining eelgrass health. The technique involved the use of modified Hydrolab instruments that measured light irradiance (PAR), turbidity, depth, salinity and temperature. The instruments were deployed directly above existing eelgrass beds before, during and after each dredging episode. Monitoring activities spanned a total period of nine months, allowing measurements to be taken under highly variable weather conditions. Results showed that the dredging events caused no measurable effect to local eelgrass populations as indicated by hours of photosynthetic saturation (Hsat). Average daily Hsat values reached a minimum of 6.6 hours, during dry-weather dredging events, but were generally above the recommended threshold of 3 to 5 hours for San Francisco Bay eelgrass populations. Although dredging events affected light regime and turbidity, their effect was short lasting. The data also showed that other factors, such as boat activity and winter storms, significantly affected turbidity levels, but were also relatively short-lived (Langis et al, SOE Poster, 1999).

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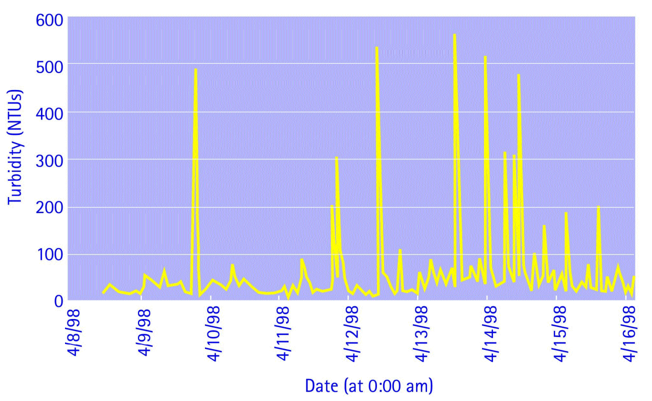
Turbidity Spikes
Due to Tugboat and Vessel Activity at Station 3



CALFED INDICATORS OF ECOLOGICAL INTEGRITY

CALFED Ecosystem Restoration Program Indicators Work Group

The CALFED Ecosystem Restoration Program (ERP) proposes to restore and/or rehabilitate various ecological processes, habitats, species and biotic assemblages in the Bay-Delta estuary and its watersheds. Ecological indicators have an essential role in any ecosystem restoration program employing a science-based adaptive management strategy. Ecological indicators are measurable ecosystem attributes or surrogates that provide information on environmental conditions, trends, and their significance;they help assess program performance. The ERP will likely employ three general interrelated types of ecological indicators:indicators of ecological integrity or health;management oriented indicators of program/project performance and success;and, public oriented indicators of program performance.

The ERP Ecological Indicators Group, composed of environmental scientists from CALFED agencies and stakeholder organizations, developed indicators of ecological integrity or health for the ERP. The group devised a process or framework for indicator development, and adopted an ecological hierarchical approach for subdividing the CALFED program area and the developing indicators. This hierarchy has landscape, ecosystem,habitat, and species/ecological process levels. The group focused on the ecosystem and landscape levels. The ecosystems are: greater San Francisco Bay, the Sacramento/San Joaquin Delta, Central Valley alluvial river-floodplain,and mountain river-riparian. Key ecosystem level attributes or characteristics for each of these ecosystems were described. These attributes are arrayed in the following categories: hydrologic and hydrodynamic, geomorphic, natural habitat, biological community, and energetics and nutrient dynamics. Additional steps in the process include delineating human stressors on the ecosystem,developing conceptual ecological models, and establishing indicator selection criteria. These tools, plus program objectives and additional scientific information, were used to develop a broad suite of potential ecosystem level indicators of ecological integrity for each ecosystem. The indicators are organized into the same categories as the attributes (see opposite).

Proposed ecosystem level indicators for greater San Francisco Bay, for example, include X2 (position of the 2 parts per thousand isohaline in the Estuary) and other salinity patterns;spatial extent and distribution of patches of all natural habitat types; toxic contaminant concentrations in sediment, selected biota,and water; population trends of selected endangered species;non-native invasive species:measures of new invasions and distribution,spatial extent, and abundance of selected species;and marsh primary productivity. The group also developed potential landscape level indicators of ecological integrity.

CALFED's proposed indicators are "work in progress" in that they need additional review and refinement by experts in appropriate disciplines (Morrison,SOE Poster, 1999).

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Potential Landscape Level Indicators of Ecological Integrity

Natural Habitat

Attribute: Landscape level habitat patterns or mosaic (e.g. spatial extent, habitat diversity, configuration).

Landscape level indices or measures of diversity (number) and spatial extent (proportional representation) of selected habitats. Relative to a reference.

Landscape level indices or measures of habitat configuration.

Number of selected habitat types not represented by at least two areas of sufficient size and ecological functions to support native species.

Attribute: Biological and physical (ecological process) connectivity at landscape level.

Net change in the number of anthoropogenic instream barriers (e.g. physical temperature, hydrodynamic related) to migratory aquatic species (e.g. anadromous fish) movement across the landscape.

Net change in the number of anthropogenic barriers to water flow, sediment transport and supply, and nutrient transport across the landscape.

Indices or measures of connectivity for organisms and ecological processes among patches of the same habitat type (for major habitat types, e.g. riparian); and/or clusters of multi-habitat complexes.

Water and Sediment Quality

Attribute: Water and sediment quality parameters within natural ranges; toxic contaminants at levels that do not adversely impact native organisms.

General Water Quality Indicator: Number of water quality standard violations per year at selected sites across the landscape.

Toxic Contaminants Indicators:

- Load Reduction: Change in amount of selected contaminants entering the system from anthropogenic sources.
- Landscape level contaminant index for selected toxics based on a scoring matrix for concentrations in water, sediment and biota.

Potential Landscape Level Indicators of Ecological Integrity

Hydrologic

Attribute: Freshwater flow patterns (timing, magnitude, and distribution) through the system.

Central Valley River Indices
(Eight Rivers, Sacramento Valley, San Joaquin Valley)

Net Delta Outflow Index

Estuarine salinity patterns (perhaps X2 and/or mean annual salinity at a series of fixed points).

Ratio of system runoff to water flowing through the system at various locations.

Biological Communities

Attribute: Spatial distribution of species.

Number of selected species exhibiting range extensions. Index of percent range extension for selected species.

Attribute: Anadromous Fishes. Broad distribution of self sustaining populations.

Distribution, movement, and/or population trends. Selected species and/or cumulative index.

Attribute : Birds. Distribution and diversity of self-sustaining populations of migratory bird species.

Population trends (e.g. abundance, reproductive success), distribution and movement. Selected species and/or cumulative index.

Attribute: Listed and other At-Risk Species (defined by CALFED Conservation Strategy).

Number of "listed" species and other at-risk species (relative to reference). The following are subsets of the above that could also serve as indicators:

- number of delisted species
- number of new (including candidate species) listings
- number of extirpated species

Index of population trends (% increase/decrease) of select listed species.

Attribute: Nonnative Invasive (Exotic) Species

Measures of new invasions/introductions

Spatial extent and distribution of selected exotic species.

Number of exotic species eradicated or no net increase in spatial extent or distribution.

NEW SCIENCE

13 Essential Ecological Indicators

Every professional who has researched, monitored or regulated portions of the San Francisco Bay-Delta River system has been asked the question, "How healthy is this ecosystem?" In order to provide an easily understandable, yet scientifically valid answer to that question, Environmental Defense convened a panel of nationally recognized scientists to develop a set of Essential Ecological Indicators.

The panel used a methodological framework to capture the complex array of structural, functional and compositional elements of ecological integrity. The panel chose not to include stressors, which require a separate set of indicators. The panel divided ecosystem attributes and processes in the estuarine system of the San Francisco Bay-Delta into six categories (see below). Panel members then selected indicators for each category, in part by referring to the more detailed and comprehensive set of indicators proposed as part of the CALFED program (see above), and to earlier work done by the Bay Institute and the University of California at Berkeley.

The panel agreed on the following 13 Essential Ecological Indicators.

HABITAT

1. Habitat Types

This indicator will measure the number of habitat types, characteristic of the pre-1850 system, that are still represented by a certain number of viable patches. It will encompass the diversity of habitat types (e.g., wetlands, forests, mudflats) essential for the ecological integrity and biodiversity of the system. A minimum number of viable representatives with protected status are needed to hedge against the possible failure of management and restoration activities. The indicator will only reflect natural patches of habitat (i.e., not manipulated habitats such as rice fields or duck clubs) that are larger than a minimum viable size, connected to migratory corridors or other habitat patches, in some sort of protected status, and that conform to the historical location of that habitat type.

2. Habitat Proportions

This indicator will measure the degree to which the extent of the major habitat types reflects their pre-1850 distribution and proportions. Such a measure is important because the restoration of habitats out of proportion to their historical distribution may produce bottlenecks in the reproduction, rearing, and growth of species (such as salmon) that use many different kinds of habitat. The indicator will only reflect natural patches of habitat (i.e., not manipulated habitats such as rice fields or duck clubs) that are larger than a minimum viable size, connected to migratory corridors or other habitat patches, and that conform to the historical location of that habitat type.

3. Water Quality Index

This indicator will provide an overall measure of water quality. Good water quality is essential for the reproduction, rearing, and growth of aquatic organisms. Eutrophication (excessive nutrients) is not a problem in the system currently. Most water quality problems in the system stem from contaminants. Toxicity scores (e.g., exposure-based metrics) for each of the major contaminant categories (selenium, mercury, PCBs, sediment contaminants, pesticides, metals, and PAHs) will be combined into a single index.

GEOMORPHOLOGY

4. River Health Index

This indicator will provide a measure of how free the system's rivers are to be rivers. River meandering and flooding is essential for sediment supply, creating and maintaining habitat, and sustaining many ecological processes. The indicator will combine measures of channel migration (essential for maintaining habitats and the exchange of nutrients), natural flooding, and sediment supply. It will also measure the total length of naturally migrating sections of rivers by adding up the segments that lack riprap, have early successional stages of forests along river banks, have large logs and branches in the river (essential for creating and maintaining fish habitat), and receive enough water flow to sustain river meandering and flooding. Sediment supply will also be incorporated in this indicator as a percentage of the channel's capacity to transport sediment and the area that is flooded at least every 5 years.

5. Marsh Health Index

This indicator will measure the growth and complexity of marshes and mudflats. It will combine a measure of marsh channel complexity (which appears to be a

PROJECT IN ACTION

Watershed Health Assessments

Local agencies and interest groups have been applying the Bay Area Watershed Science Approach (WSA), developed by the San Francisco Estuary Institute, on creeks in Napa, Sonoma, Marin, Santa Clara, Alameda and Contra Costa counties. Through the WSA, participants develop detailed scientific assessments of past and present conditions for sediment sources, water supplies, wildlife habitat and land use, which in turn provide information on the beneficial uses of Bay Area watersheds.

The WSA combines maps of historical conditions with modern aerial photography in a Geographic Information System (GIS) to develop quantitative analyses of changes in landscape and landscape use. These analyses are combined with intensive field studies of existing conditions of the hill slopes, terraces, and stream banks and beds to help explain any major changes in sediment and water supply, and to what extent people have caused these changes.

The WSA can provide baseline watershed assessments to help design stream restoration projects, prioritize resource protection activities and public land acquisition for conservation and preservation purposes, test Best Management Practices (BMPs) for pollution prevention, validate simulation models of watershed processes, explain watershed form and function to local residents, stratify a watershed for sampling water quality, set science-based goals for watershed health, compare one watershed with another, and design programs for monitoring progress or regress relative to local watershed goals. Applications of the WSA yield important new information about the nature of Bay Area watersheds (Collins et. al, SOE Poster, 1999).

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Essential Ecological Indicators - continued

good proxy for habitat quality) with measures of marsh plain elevation and advancement of marsh edge. As data become available on the bathymetry of the Bay, it will also be incorporated.

HYDROLOGY

6. Pre- and Post-Dam Flows

This indicator will measure proximity to pre-disturbance river conditions. The flow of water created and maintained the aquatic habitats that sustained the abundant fish, water fowl, and riparian communities that once existed in the system. Flow has been dramatically altered by dams in this system. This indicator will describe current flow conditions compared to those of the pre-dam era. Mean annual flow, 2-year and 5- year peak flows, spring flows between April and June, and base flows in August and September will be incorporated into a single index and compared to pre-dam parameters. Variation in flows from year to year is also important for maintaining habitats and ecological processes. Flow variation pre- and post-dam will also be incorporated into this indicator.

Note: Additional indicators are still under consideration in order to reflect the natural pattern of variability — both interannual and intra-annual — well as estuarine circulation and salinity patterns.

ENERGY AND NUTRIENT FLOW

7. Productivity Index

The flow of nutrients and the production of food for wild organisms are critical ecological processes. This indicator will measure water column productivity (as evidenced by the annual spring phytoplankton bloom in South Bay and the amount of chlorophyll a in the North Bay and Delta) as well as the contribution of marsh productivity (as measured by tracers of marsh production within suspension feeders like clams). It will also incorporate the absence of toxic algal blooms. These and other measures will be combined into a single index.

NATIVE BIOTA

Five indices will measure the capacity of the system to support the reproduction, rearing, and growth of native plants and animals. The biota were separated into four functional groups that are essential components of the native system and about which there is some information. Representative species within the four functional groups will be selected according to criteria reflecting the species' ecological characteristics: area-limited, dispersal-limited, resource-limited, process-limited, keystone or ecologically pivotal, and endemic. These five biotic indices may be kept separate or combined into a single index.

8. Fish Index

Native anadromous fishes; native resident pelagic fishes in bay, delta, alluvial rivers and upland rivers; and native resident demersal fishes in bay and delta (e.g., sharks and rays)

9. Bird Index

Neotropical migrant songbirds (riparian and landscape); water birds (shorebirds, wading birds, ducks); and raptors.

10. Vegetation Index

Riparian vegetation (alluvial and upland rivers); and wetland vegetation (bay, delta, alluvial rivers).

11. Habitat Specialists

Fragmentation-sensitive species; clapper rail, red-legged frog, salt marsh harvest mouse etc.

12. Decimated Species

A fifth index will describe presence and abundance trends of native species that might have been decimated or extirpated in the system (and that may rebound in successful restoration), such as the native oyster, blue mussels, and the mud mussel.

13. Disturbance

Percent of abundance or biomass of fish, bird, vegetation, and habitat specialists made up of exotic species. San Francisco Bay appears to be one of the most highly invaded estuaries in the world. This indicator will measure the extent to which non-native (exotic) species have replaced native species.

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ACRONYMS KEY

DWR-Department of Water Resources

CALFED-CALFED Bay-Delta Program

CDFG-California Department of Fish and Game

MWD-Metropolitan Water District

SFBCDC-San Francisco Bay Conservation and Development Commission

SFBRWQCB-San Francisco Bay Regional Water Quality Control Board

SFEI-San Francisco Estuary Insitute

SFEP-San Francisco Estuary Project

SJSU-San Jose State University

SWRCB-State Water Resources Control Board

USBR-United States Bureau of Reclamation

USEPA-United States Environmental Protection Agency

USFWS-United States Fish and Wildlife Service

USGS-United States Geological Survey

Page numbers appearing in bold refer to the page number in this report.